

## MORPHOLOGY AND RELATIONSHIPS OF TROCHODENDRON AND TETRACENTRON

### II. INFLORESCENCE, FLOWER, AND FRUIT

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*With five plates*

#### INTRODUCTION

THE FIRST paper (4) of this series dealt with the morphology of the stem, root, and leaf of *Trochodendron* and *Tetracentron* and with significant palaeobotanical data. The present paper will deal with the morphology of the inflorescence, the floral organs, and the fruit, and will conclude the series with a general discussion of the relationships of these remarkable dicotyledons. In so doing, we shall present evidence in support of Dr. Smith's (10) conclusion regarding the close affinities between the two genera.

#### INFLORESCENCE

**TROCHODENDRON.** The buds of this genus have numerous scales. When a vegetative bud expands, the smaller outer scales soon drop off, but the inner larger cataphylls are persistent for a season and become separated by internodal elongation. A pseudoverticillate cluster of leaves of varying sizes develops above these cataphylls, and the axis terminates in a maturing bud. The growth of such a vegetative shoot obviously is monopodial.

When a flower bud of *Trochodendron* expands, the numerous cataphylls are early deciduous, and the stem is extended as the primary axis of an inflorescence, *Fig. 1*. This rachis usually, but not invariably, terminates in a flower. It bears numerous elongated bracts, in the axils of most of which secondary flower-bearing axes are formed. In certain cases, the lowermost of these structures are branched, thus giving rise to tertiary floral axes, *t. fl.*, *Fig. 1*. Even when the rachis terminates in a flower, the uppermost bracts tend to be reduced in size and have no flowers in their axils. Elongated bracteoles do not develop on secondary axes except where these axes are branched. A vegetative bud occurs in the axil of the last sterile scale at the base of the inflorescence, *ax. b.*, *Fig. 1*. This bud extends the vegetative part of the shoot, which, therefore, is of a sympodial type.

It is evident, accordingly, that the inflorescence of *Trochodendron* is terminal and that it is a raceme-like pleiochasium with occasional tertiary floral axes. The occurrence of such tertiary axes and the not infrequent absence of a terminal flower render difficult the acceptance of Wagner's (12) interpretation of the inflorescence as an interrupted "primanpleiochasium."

**TETRACENTRON.** The vegetative buds of the long shoots of *Tetracentron* have two elongated scales, occasionally reduced to one in the axillary bud



closest to the apex of the shoot. Within the bud scales there is a tiny leaf, having a terminal bud primordium enclosed within its stipular flange. The extension of the shoots is by monopodial development.

The flower buds of *Tetracentron* are borne on short shoots, and at first are enclosed within the stipular flanges of a leaf (*o. lf.*) as illustrated in *Fig. 3*. Each matured flower bud has two scales, within which are an incipient inflorescence (*infl. ax.*) and a short axis bearing a small leaf (*lf.*) enclosed within an enveloping scale (*br. 3*). The subsequent development of the short axis, *Fig. 2*, crowds the inflorescence into an apparently lateral position. That the inflorescence actually is terminal and the leaf-bearing shoot axillary is indicated, however, by topographical relationships within the flower bud, *Fig. 3*. The occurrence of a bud (*ax. b.*) in the axil of the leaf (*o. lf.*) demonstrates that the flower bud is terminal. Similarly, the occasional formation of a rudimentary bud in the axil of the lower bud scale (*br. 1*) indicates that the inflorescence is terminal and that the short leaf-bearing axis is lateral, i.e. develops from a bud in the axil of the inner scale (*br. 2*) of the flower bud. Such an interpretation of the morphology of the short shoot is supported by the orientation of the scale (*br. 3*) of the inner axillary bud (*t. m.*). This scale is set at right angles to the scales (*br. 1* and *2*) of the flower bud, and its orientation in relation to the axis of the inflorescence is the same as that of the scales of axillary buds to the axis of long vegetative shoots.

The apical primordium (*t. m.*) of the leaf-bearing axillary shoots forms the flower bud of the next year. It is evident, accordingly, that the inflorescences of *Tetracentron* are terminal and that the development of the short shoots is sympodial. The inflorescence is a spike with numerous sessile flowers, each subtended by a minute bract, *Fig. 4, br.* The flowers tend to be arranged in false whorls. Four decussate bracts are usually present at the apex of the axis, but occasionally the rachis may terminate in a flower.

#### FLOWERS

**PERIANTH.** The sessile, tetramerous flowers of *Tetracentron*, *Fig. 4*, have four sepals oriented opposite to the stamens. The flowers of *Trochodendron* generally are considered to be without a perianth, but Hutchinson (7), in defining the Trochodendraceae (*Euptelea* and *Trochodendron*), states that sepals are absent or very minute. Most of the axillary flowers of the inflorescence have a pair of tiny, unvascularized<sup>1</sup> scales, *br.*, *Figs. 6* and *7*, that commonly are attached to the base of the torus or less frequently at a somewhat lower level. The terminal flower of the rachis may have three or four of these rudimentary appendages. The higher levels of attachment suggest that the scales may be vestiges of a calyx. It should be noted in this connection, however, that the broad bases of the scales are decurrent and embossed, *Fig. 7*, as are those of the bracts on the rachis and of elon-

<sup>1</sup> In contrast to the normal elongated bracts and bracteoles of the inflorescence, which have a single vascular strand. The minute bracts of *Tetracentron* also have a single trace.



gated bracteoles on branched secondary, flower-bearing axes. Furthermore, the androecium is perigynous and the stamens appear to be attached to the dorsal surfaces of the carpels. The subtending scales may, therefore, be rudimentary bracteoles that have been upwardly displaced onto the surface of the receptacle. It is unfortunate that there are no vascular strands in these structures to aid in their interpretation.

**ANDROECIUM.** The numerous stamens of *Trochodendron* are borne individually upon cushions that tend to be linearly arranged on more or less embossed and decurrent ridges of the dorsal surface of the carpels, *Figs. 6* and *7*. The four stamens of *Tetracentron* are borne alternately to the carpels and do not exhibit external evidences of perigyny.

The stamens of the two genera are, however, of a fundamentally similar morphological type. The filaments terminate in a relatively massive instead of a much constricted connective as in *Drimys* (Bailey and Nast, 2), and the four sporangia are not conspicuously protuberant as in many dicotyledons. The endothecium is neither as restricted as in *Degeneria* and *Himantandra* (1) nor as extensive as in the Winteraceae, where it completely jackets the sporangia. In *Tetracentron* and *Trochodendron*, it is a continuous subepidermal layer, not only external to the sporangia, but also extending across the adaxial and abaxial sides of the connective, *Figs. 22* and *23*. It differentiates first in the region of the sporangia and subsequently in the connective. Its maturation in *Trochodendron* is completed before dehiscence of the pollen, whereas its differentiation in the connective of *Tetracentron* may be markedly retarded. Dehiscence is longitudinal-lateral, giving to the anther a bivalvular appearance.

**POLLEN.** Van Tieghem (11) described the pollen of *Trochodendron* as simple, spherical grains with three pores, the pollen of *Tetracentron* as simple, somewhat flattened pentagonal grains with smooth surfaces and having five pores. He provided no illustrations, and his descriptions are inadequate and quite inaccurate in the case of *Tetracentron*.

As indicated in *Figs. 24* and *25*, the pollen of both genera are tricolpate with papillate, crest-like thickenings on the floor of each furrow. The grains have a conspicuous reticulately thickened outer surface, the appearance of which changes at different focal levels. If the outermost surface of the reticulation is brought into focus, the ridges are rather broad and the pits are small. At a lower focal level, the ridges appear quite narrow and the pits considerably wider. This difference in surface views is due to the conformation of the ridges and can be most convincingly demonstrated in thin sections of pollen grains cut at right angles to their surface. Such a section, one micron in thickness, is illustrated in *Fig. 26*. The basal part of the ridges is very narrow, whereas the external part is much thicker, appearing almost bulbous in sectional view. The ridges project outward from a thick relatively homogeneous layer of the exine, within which is a thin, very hyaline layer, presumably the intine. It is the latter layer that forms the floor of the furrows and supports the crest-like thickenings of papillate exine.



Although the pollen grains of *Tetracentron* and *Trochodendron* are entirely unlike those of the Magnoliaceae and other ranalian families having monocolpate and derived types of pollen, they are of a general morphological type that occurs at times in other dicotyledonous families, e.g. in *Disanthus* (Fig. 27) of the Hamamelidaceae.

**GYNOECIUM.** The carpels of *Tetracentron* and *Trochodendron* are laterally concrescent, with free styles, Figs. 4 and 7. As in *Degeneria*, the section *Tasmannia* of *Drimys*, and *Himantandra*, the megasporophylls are adaxially folded or conduplicate with their ventral (upper) surfaces closely approximated, Figs. 9 and 12, thus leaving a cleft-like opening into the locule. The margins of the carpels are free except at the base of the syncarpous gynoecium, level A, Fig. 7. The conduplicate form of the carpel is not confined to the region of the locule but occurs throughout the style, Figs. 10 and 13.

The carpels have a conspicuous dorsal bulge which is greatly accentuated in *Tetracentron*, *d. blg.*, Figs. 4, 12 and 13, and is nectariferous according to van Tieghem (11) in *Trochodendron*, Fig. 7. Insects evidently are attracted to this succulent parenchymatous region, for the dorsal bulge has frequently been chewed away in herbarium specimens of *Trochodendron*, Fig. 6.

In *Tetracentron*, where abaxial deformation of the carpels does not occur until after anthesis, the placentae are oriented parallel to the vertical axis of the flower and the ovules are set at right angles to this axis. In *Trochodendron*, where more or less abaxial deformation occurs prior to anthesis, the numerous ovules are set at right angles to the placentae, which are oriented in various diagonal positions in relation to the vertical axis of the flower, Fig. 7. The placentae are situated in the upper part of the locule, and particularly in the case of *Trochodendron* far back from the free margins of the conduplicate megasporophyll, Fig. 9.

**OVULES.** The ovules of *Trochodendron* are considered by van Tieghem (11) to have a unique development and morphological form, unlike that of any other known representative of the angiosperms. Each ovule has a pronounced sub-chalazal extension, Fig. 15, in which the vascular strand (or the procambium) makes a "hair-pin" turn. The nucellus and integuments develop laterally instead of terminally on the ovulary lobe, Fig. 14. The sub-chalazal projection, therefore, is actually an extension of the apex of the ovulary lobe and not to be confused with the unvascularized sub-chalazal emergences of *Bilbergia* and other genera.

Our observations, based upon somewhat inadequate herbarium material, tend to support van Tieghem's generalizations regarding the ovules of *Trochodendron*, and indicate that homologous, but less accentuated, characters occur in the ovules of *Tetracentron*. The sub-chalazal extension is present in ovules at an early stage of development where no procambium is discernible, Fig. 14, and also in younger ovules with incipient integuments and no evidences of a megaspore.

The matured ovules have two integuments. The outer one consists of



three layers of cells in both *Tetracentron* and *Trochodendron*, and is more massively developed at the micropylar end of the ovules. The inner integument is composed of two layers of cells.

VASCULARIZATION OF THE FLOWER. The elongated pedicel of *Trochodendron* contains a eustele composed of a varying number of vascular bundles. These bundles tend to increase in number toward the base of the flower. They branch and anastomose, forming new interfascicular regions as in the pedicel of *Drimys* (Nast, 8). Certain of them become cortical bundles<sup>2</sup>, *cor. b.*, *Fig. 7*, at the base of the receptacle. They are variable in number, commonly about as numerous as the stamen-bearing ridges on the dorsal surface of the carpels. Each of the cortical bundles tends to give rise to three or four traces, one for each of the stamens of a particular ridge. Occasionally the cortical bundles branch and form twice as many staminal traces. Rarely does the individual trace of a stamen arise directly from the eustele.

The dorsal traces of the carpels diverge from the eustele at a level slightly below that of the base of the locules, *d.t.*, *Fig. 7*. They usually are discrete strands, although occasionally one may arise from a stelar bundle common to it and either a ventral or cortical bundle. The dorsal trace forms, *level B*, *Fig. 7*, two lateral branches, *l.d.t.*, *Figs. 7* and *8*. Toward the upper part of the carpel, the median and lateral dorsal strands divide and anastomose, forming a network of strands (*Fig. 7* shows the network of half of one carpel). A number of tiny branches of the dorsal strands extend a short distance into the parenchymatous dorsal bulge of the carpels and end blindly, *a*, *Figs. 7* and *9*.

The bundles which ultimately form the ventral traces of the carpels usually arise from stelar bundles that are common to them and to the cortical bundles which form the traces of the stamens, *Fig. 7, right*. At the level of the bases of the carpels, there is one of these bundles in each of the septa formed by the lateral concrescence of carpels, *v.b.*, *Fig. 7*. At a higher level, *level B*, *Figs. 7* and *8*, these bundles divide, their halves becoming ventral traces of the adjacent carpels, *v.t.*, *Fig. 7*. Most of the ovules are vascularized by branches of the two ventral traces. However, a dorsal strand anastomoses with each ventral bundle and the uppermost ovules are, therefore, vascularized by these fused strands, as in many of the Winteraceae (Bailey and Nast, 3).

The bundles of the eustele at the base of the sessile flowers of *Tetracentron* become abruptly and almost simultaneously dissociated into traces. The four large and very short outermost bundles, which are basically cortical, *cor. b.*, *Fig. 11*, produce four calycine traces, one to each sepal, and four staminal traces, one to each stamen. Occasionally a sepal may have an extra trace, *Fig. 12*. The vascularization of the carpels is fundamentally similar to that of the carpels of *Trochodendron*. Ordinarily there is a large dorsal trace, *d.t.*, *Fig. 11*, in the base of each carpel. This trace forms three strands, *Fig. 11, carpel at right*, which divide, *Fig. 11*, anastomose, *Fig. 12*,

<sup>2</sup> For definition of term refer to Nast (8).



and may redivide, *Fig. 13*. There are, in addition, four bundles which form ventral traces. At the base of the carpels, one of these bundles occurs in each of the septa of the laterally concrescent carpels. As in *Trochodendron*, these bundles divide to form ventral traces of adjacent carpels, *Figs. 11 and 12*. Both the ventral and the dorsal strands extend upward to the apex of the style. There is no fusion of ventral and dorsal strands in the vascularization of ovules, as in *Trochodendron*, possibly owing to the reduction in size of the carpels and in the number of ovules.

#### FRUIT AND SEED

The fruit of *Trochodendron* is a follicetum with ventral, loculicidal dehiscence. It is somewhat flattened at the apex, *Fig. 6*, with the styles of the follicles bent outwardly, forming spur-like appendages. In the development of the fruit the conduplicate ventral side of the sporophyll enlarges disproportionately to the dorsal side, thus displacing the styles and causing the fruit to become flattened at the distal end. The placentae, which are in a diagonal position in the flower, *Fig. 7*, assume in the fruit an apical or horizontal orientation with the seeds pendent in the locules. The fertile and interspersed sterile seeds are in two rows, one row on each placenta. The raphes or dorsal sides of the seeds are arranged back to back. This orientation of the seeds is the same as that of the ovules, which are heterotropous according to Agardh's terminology (Gray, 6, p. 282).

The fruits of *Tetracentron*, although superficially very different, are essentially similar in structure. The fruit of *Tetracentron* also dehisces loculicidally. However, the abaxial deformation of the megasporophyll, due to the extreme development of the conduplicate ventral side, is much more exaggerated in *Tetracentron* than in *Trochodendron*. The dorsal side or bulge, *d. blg.*, *Figs. 4 and 5*, retains approximately its original size. The ventral side, however, increases to such an extent that the styles, which are upright in the flower, assume a basal position, *Figs. 4 and 5*. There is also greater growth on the ventral or grooved sides of the styles than on the dorsal sides, so that the styles also curve abaxially, thus producing four hooked spurs in the fruit. With the over-extended ventral sides of the sporophylls, the placentae are brought from a vertical position at anthesis to a horizontal and apical position in the fruit. The seeds are thus pendent, with their dorsal sides or raphes back to back, as in *Trochodendron*.

The seeds of the two genera are strikingly similar in their anatomy. In both *Trochodendron* and *Tetracentron*, the raphe forms an embossed ridge throughout the length of the seed. Within this ridge is the raphe-bundle, which is surrounded by thick-walled cells, *Figs. 18 and 19*. The subchalazal ends of the seeds are extended into a projection which is vascularized, *Figs. 16 and 17*. The funiculus is fairly short, with the micropylar end of the outer integument greatly enlarged and encroached upon it. The average size of the seed of *Tetracentron* is slightly smaller than that of *Trochodendron*.



Van Tieghem (11) and Netolitzsky<sup>3</sup> (9) report two seed coats in *Trochodendron*. According to van Tieghem, the internal coat arises from the inner integument of the ovule and is composed of two layers of thin-walled, colorless cells. The outer seed coat is brown and has three layers, of which the medium is sclerous and arises from the outer integument of the ovule. In the case of *Tetracentron*, he merely mentions that the seed has a thick external integument, lacunous and soft.

Our observations on the seed coats do not agree with van Tieghem's descriptions. The three-layered outer integument of the ovule matures into an outer seed coat of thin-walled cells in both *Trochodendron* and *Tetracentron*, Figs. 18, 19, and 21a. In *Trochodendron*, the cells of the innermost layer of the external seed coat have thickened (cutinized?) anticlinal walls and a thickened external (i.e. adjacent to the inner seed coat) periclinal wall. It has, therefore, typical epidermal characteristics. The cells of the other two layers become flattened radially, Fig. 19, but are greatly extended longitudinally, giving a striated appearance to the body of the matured seed when cleared in NaOH. In *Tetracentron*, this inner layer is only slightly thickened, but the outer seed coat forms ridges by increase in size and number of its cells. These cells grow and expand into any available space between the seeds, which are tightly packed in the fruit. The resulting ridges give a winged appearance to the seeds of *Tetracentron*, Figs. 16 and 18, *opposite raphe*.

The external layer of the inner seed coat of both genera is sclerenchymatous. The cells are small in cross sectional diameter, Figs. 18, 19, and 21a, but greatly elongated, Fig. 20. This layer or sclerotesta also appears striated, due to its elongated cells, and is readily visible in cleared seeds, Figs. 16 and 17. Internal to the sclerotesta are thin-walled cells which are derived from the inner layer of the internal integument and the nucellus of the ovule.

The endosperm, which constitutes the greatest volume of the seed, is composed of thin-walled, isodiametric cells. The tiny embryo, embedded in the endosperm at the micropylar end of the seed, is either undifferentiated or has incipient cotyledonary development, Fig. 20.

In the sterile seeds, the endosperm is usually absent (a small amount is present in occasional sterile seeds of *Tetracentron*). Often the sclerenchymatous layer is all that remains of the inner seed coat. The inner layers of the outer seed coat, especially of *Trochodendron*, become densely sclerenchymatous. The numerous sterile seeds of *Trochodendron* are darkly and conspicuously castaneous.

#### RELATIONSHIPS

Although *Tetracentron* and *Trochodendron* differ conspicuously in their habit of growth, in the form and vascularization of their leaves, and in the grosser characters of their inflorescences and flowers, they exhibit many peculiarities of internal structure, organization, and development that are

<sup>3</sup> Netolitzsky's description is apparently taken from van Tieghem.



fundamentally similar and that serve to differentiate these plants from other woody ranalian genera.

As emphasized in the first paper (4) of this series, the woods of *Tetracentron* and *Trochodendron* are remarkably similar and differ from those of other known angiosperms, including the vesselless Winteraceae. Particularly significant in this connection are transitions from typical transverse to diagonal and longitudinal planes of cell division in the maturation of wood parenchyma strands. This aberrant trend of cytological specialization is much exaggerated in *Tetracentron*.

The secondary phloems of the two genera are of the same morphological type. They do not have the precocious flaring of the multiseriate rays and the early stratification into narrow, alternating arcs of soft bast and fibers that occur so characteristically in the Magnoliaceae (sensu stricto), Degeneriaceae, and Annonaceae. Nor is there a sclerification of the multiseriate rays close to the cambium, as in *Euptelea* and many Winteraceae.

Although typical leaves of adult *Trochodendron* are exstipulate with multilacunar nodal attachments and commonly without buds in their axils, the earlier leaves formed by seedlings resemble the leaves of *Tetracentron* in having trilacunar nodal attachments and sheathing leaf bases that enclose axillary buds. Furthermore, the stomata of the two genera are of a peculiar and similar structural type.

There are similar tendencies toward reduction of internodal elongation both in the vegetative axes and the inflorescences, leading in *Trochodendron* to the periodic formation of pseudovercils of leaves and to the clustering of axillary flowers on the upper part of the rachis, and in *Tetracentron* to the production of short shoots and of false whorls of sessile flowers on the rachis.

The complex patterns of vascularization of the flowers are essentially similar in both genera. The form of the open, conduplicate, laterally concrescent carpels is fundamentally the same. There is a similar abaxial deformation of the follicles which is merely more extensive in *Tetracentron* than in *Trochodendron*. The placentation, stamens, pollen, ovules, and seeds exhibit minor differences only. The vascularized, sub-chalazal projections of the ovules and seeds appear to be as unique among angiosperms as is the structure of the vesselless xylem.

The totality of the developmental, anatomical, and other morphological similarities between *Trochodendron* and *Tetracentron* is so large as to leave no doubt regarding the close affinities of the two genera. Whether the plants should be placed in a single family or in two separate but closely related monotypic families depends upon the taxonomic emphasis that is placed upon obvious differences in their foliage, inflorescences, and flowers.

As will be shown in subsequent papers by Dr. Smith and ourselves, the genus *Euptelea* exhibits no significant similarities to *Tetracentron* and *Trochodendron* in any of its vegetative or reproductive parts and, therefore, cannot be associated with *Trochodendron* in the Trochodendraceae.

It should be emphasized in conclusion that there are no cogent evidences



of close relationship between either *Tetracentron* or *Trochodendron* and the Magnoliaceae (sensu stricto), Degeneriaceae, Himantandraceae, Winteraceae, Schisandraceae, Cercidiphyllaceae, or Eucommiaceae.

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## EXPLANATION OF PLATES

## PLATE I

*Ax. b.*, axillary bud; *br.*, bract; *br. sc.*, bract scar; *d. blg.*, dorsal bulge; *f. w.*, floral whorl; *infl. ax.*, inflorescence axis; *infl. sc.*, inflorescence scar; *lf.*, leaf; *lf. sc.*, leaf scar; *n. br.*, naked bract; *o. lf.*, old leaf; *pd.*, peduncle; *st. pd.*, stamen pad; *st. sc.*, stamen scar; *sty.*, style; *t. m.*, terminal meristem; *t. fl.*, tertiary flower; *v. su.*, ventral suture.

FIG. 1. *Trochodendron*. Diagrammatic drawing of an inflorescence. FIG. 2. *Tetracentron*. Diagrammatic drawing of an opening floral bud on a short shoot; internodes elongated. FIG. 3. *Tetracentron*. Diagram of floral bud. FIG. 4. *Tetracentron*. Flower, approx.  $\times 26$ . FIG. 5. *Tetracentron*. Fruit, approx.  $\times 29$ . FIG. 6. *Trochodendron*. Fruit, approx.  $\times 7$ .

## PLATE II

*A.*, vascular strands in dorsal bulge; *br.*, bract; *cor. b.*, cortical bundle; *d. b.*, dorsal bundle; *d. t.*, dorsal trace; *fil.*, filament of stamen; *l. d. b.*, lateral-dorsal bundle; *ov. t.*, ovulatory trace; *st. cu.*, staminal cushion; *st. sc.*, staminal scar; *st. t.*, staminal trace; *v. b.*, ventral bundle; *v. t.*, ventral trace.

FIG. 7. *Trochodendron*. Flower; two carpels removed at *level A* and two removed at *level B* to show cross sectional view; perpendicular shading lines indicate cut surfaces; epidermal surface represented by stippling; only half of dorsal vascular system shown in one carpel; approx.  $\times 18$ .

## PLATE III

*A.*, vascular strands in dorsal bulge; *cor. b.*, cortical bundle; *d. b.*, dorsal bundle; *d. blg.*, dorsal bulge; *d. l. b.*, dorsal-lateral bundle; *d. l. t.*, dorsal-lateral trace; *d. t.*, dorsal trace; *l. se. b.*, lateral sepal trace; *ov. t.*, ovulatory trace; *se.*, sepal; *se. t.*, sepal trace; *st.*, stamen; *st. t.*, stamen trace; *v. t.*, ventral trace.

FIG. 8. *Trochodendron*. Transverse section of flower from region comparable to *level B* in Fig. 7,  $\times 12$ . FIG. 9. The same. Transverse section through placentae,  $\times 12$ . FIG. 10. The same. Transverse section through styles,  $\times 12$ . FIGS. 11-13. *Tetracentron*. Transverse sections through flower comparable to sections in Figs. 8-10, approx.  $\times 31$ .

## PLATE IV

*Em.*, embryo; *end.*, endosperm; *fu.*, funiculus; *i. int.*, inner integument; *mi.*, micropyle; *o. int.*, outer integument; *ov. b.*, ovulatory bundle; *ra.*, raphe; *sc. l.*, sclerenchymatous layer.

FIG. 14. *Tetracentron*. Young ovule, approx.  $\times 114$ . FIG. 15. *Trochodendron*. Young ovule, approx.  $\times 76$ . FIG. 16. *Tetracentron*. Fertile seed cleared in NaOH, approx.  $\times 24$ . FIG. 17. *Trochodendron*. Fertile seed cleared in NaOH, approx.  $\times 24$ . FIG. 18. *Tetracentron*. Transverse section through middle of fertile seed, approx.  $\times 8\frac{1}{2}$ . FIG. 19. *Trochodendron*. Transverse section through middle of fertile seed, approx.  $\times 8\frac{1}{2}$ . FIG. 20. *Tetracentron*. Longitudinal section of micropylar end of fertile seed, approx.  $\times 8\frac{1}{2}$ . FIG. 21. *Trochodendron*. Transverse section through middle of sterile seed, approx.  $\times 8\frac{1}{2}$ . FIG. 21a. *Trochodendron*. Transverse section through outer seed coat and sclerenchymatous layer of fertile seed, approx.  $\times 764$ .

## PLATE V

FIG. 22. *Trochodendron*. Transverse section through anther,  $\times 126$ . FIG. 23. *Tetracentron*. Transverse section through anther,  $\times 103$ . FIG. 24. *Trochodendron*. Pollen grain, *pap.*, papillae; *rid.*, ridges of reticulation,  $\times 1390$ . FIG. 25. *Tetracentron*. Pollen grain,  $\times 1390$ . FIG. 26. *Trochodendron*. Section of pollen grain showing structure of wall, approx.  $\times 1675$ . FIG. 27. *Disanthus cercidifolius* Maxim. Pollen grain,  $\times 1390$ .

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